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Performance Analysis of DCT Based OFDM System in Parametric Variation Under Rayleigh and Fading Channel

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Abstract: Multicarrier modulation, and especially OFDM, (Orthogonal Frequency Division Multiplexing) is one of the remising candidates that uses a set of subcarriers in order to broadcast the information symbols in parallel through the communication channel. It permits the communication system to broadcast the data at a lower rate on plurality of subcarriers and the throughput of multicarrier system remains as single carrier system. Here we are employing OFDM with DCT (Discrete Cosine Transform) for our image processing system. DCT is a Fourier-related transform resembles discrete Fourier transform (DFT), but deals only with real numbers. In this research, we have done performance assessment for the given system based on BER (Bit Error Rate), MSE (Mean Squared Error), & PSNR (Peak Signal to Noise ratio) under parametric variation i.e. Compression level, Channel used, Modulation method used. Given system has been tested for Rayleigh and fading channel under parametric variation.

Keywords: AWGN, BER, DCT, OFDM, PSNR, QAM.

I. INTRODUCTION

Thriving demand of wireless multimedia applications,the required bit rate / high speed are achieved just because of OFDM (Orthogonal Frequency Division Multiplexing) multicarrier transmission [1].

Orthogonal frequency division multiplexing (OFDM) is a kind of multicarrier modulation scheme equipped with subcarriers which possess orthogonal property. Let X_k for k=0 to n-1 be the set of complex symbols to be broadcasted by multicarrier modulation, the continuous time domain MCM signal can be expressed as:

$$\left.\begin{aligned} x(t) &= \sum_{k=0}^{N-1} X_k \exp(j2\pi f_k t) \quad \text{for } 0 \le t \le T_s \\ &= \sum_{k=0}^{N-1} X_k \varphi_k(t) \quad \text{for } 0 \le t \le T_s \\ &\text{where } f_k = f_o + k\Delta f \text{ and} \\ \varphi_k(t) &= \begin{cases} \exp(j2\pi f_k t) & 0 \le t \le T_s \\ 0 & \text{otherwise} \end{cases} \quad \text{....[1]} \end{aligned}\right\}$$

For k = 0, 1, 2...N −1. The subcarriers become orthogonal if Ts Δ f = 1, and such a modulation scheme is called OFDM, where Ts and Δf are called the OFDM symbol duration and the subcarrier frequency spacing respectively. In case of orthogonal subcarriers x(t)denotes a time domain OFDM signal.The orthogonality among sub carriers can be viewed in time domain as shown in Fig.1.1 .Each curve represents the time domain view of the wave for a subcarrier. As seen from Fig 1.1, in a single OFDM symbol duration, there are integer numbers of cycles of each of the subcarriers[3].

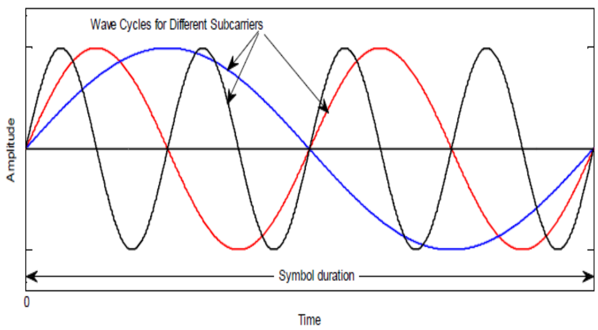

Fig 1.1 Time domain representation of the signal waveforms to show orthogonality among the subcarriers

Under optimal conditions the OFDM signal can be demoded without any interference between the subcarriers. But in situation of time dispersive channel, the orthogonality between the subcarriers gets disordered because the demodulator correlation interval for one path will overlie with the symbol boundary of different path.[4][5].

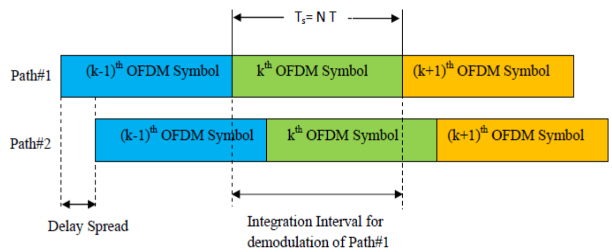

Fig 1.2 Time dispersion and received signals timing

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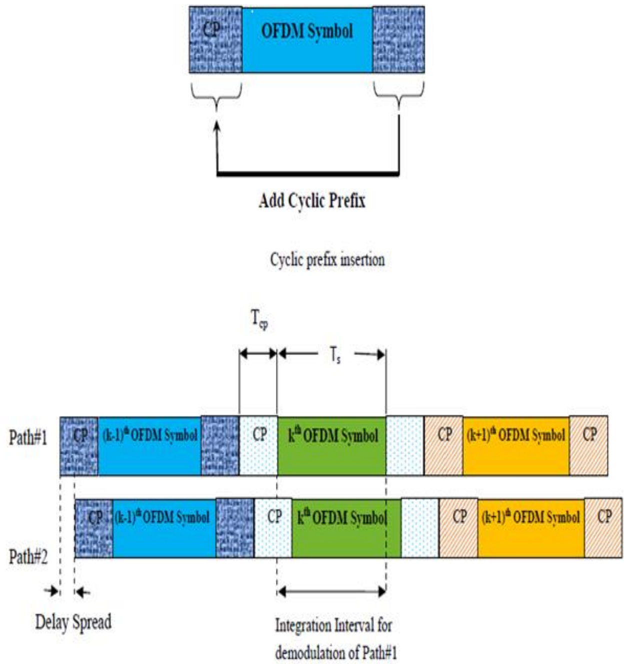

Fig 1.3 Time dispersion and received signal using cyclic prefix insertion

To overcome the problem and to make an OFDM signal truly unresponsive to time dispersion of the radio channel, cyclic-prefix (CP) insertion is typically used. As illustrated in Fig. 1.3 .cyclic-prefix insertion signifies that the last part of the OFDM symbol is duplicated and interpolated at the starting of the OFDM symbol. Cyclic-prefix interpolation is thus increases the length of the OFDM symbol duration from TS to TS+ TCP, where TCP is the length of the cyclic prefix. As illustrated in Fig. 1.2 and Fig 1.3, if the correlation at the receiver side is still carried out over a time interval TS, subcarrier orthogonality will be preserved in case of a time-dispersive channel, as long as the period of the time dispersion is shorter than the length of cyclic-prefix. At the receiver side, the corresponding samples are rejected before OFDM subcarrier demodulation.

OFDM symbol by using a serial to parallel converter and then a cyclic prefix of suitable length is inserted to combat the effect of ISI. Finally the discrete time OFDM signal is converted into analog OFDM signal and amplified to the desired power level. The obtained signal is transmitted over communication channel.The received signal at the receiver is first converted into analog by using the D/A converter and cyclic prefix is removed. The obtained signal is applied to a serial to parallel converter and then subcarrier demodulation is performed by using FFT operation. After that one tap frequency equalization can be utilized to cancel the effect of multipath fading channel and then passed through a parallel to serial converter to obtain serial data signal. Finally, signal is demodulated to get the desired data signal.[6]

OFDM signal received at the receiver is first converted into digital and then applied to serial to parallel converter. After that FFT of the signal obtained from is performed to achieve the subcarrier demodulation. As seen from Fig 3.10, that FFT operation used in OFDM demodulator eliminates the requirement of N co-relaters operating in parallel to demodulate the multicarrier modulator.[7]

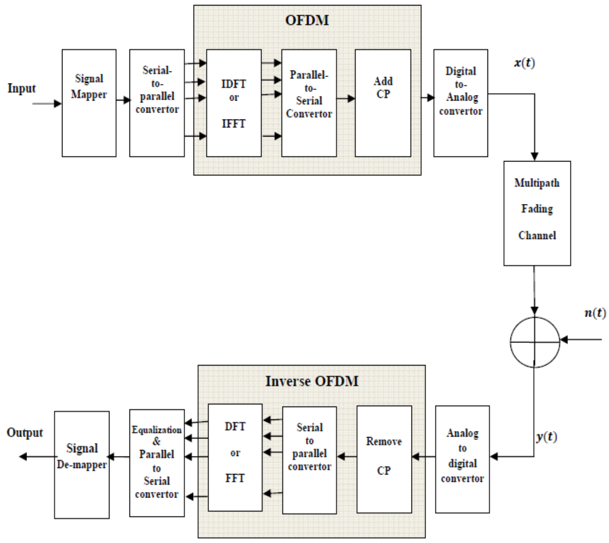

Fig 1.4 OFDM transceiver

II. DCT-OFDM IMAGE PROCESSING SYSTEM

The DCT is a Fourier-related transform. It uses only real numbers. The simplest way to formulize DCT to transform N real numbers xo,…..,xN-1 into N real numbers X0,....., XN-1 is

$$X_k = \sum_{n=0}^{N-1} x_n \cos\left[\frac{\pi}{N}\left(n+\frac{1}{2}\right)(k)\right], k = 1, \ldots\ldots\ldots, N-1 \quad \text{.... [2]}$$

The sequences normally used in any kind of transform from one domain to the other are referred to as the basis sequences, and these are complex recurring sequences in case of Discrete Fourier Transform...

Discrete Cosine Transform (DCT) expresses a sequence of definite data points in terms of a sum of cosine functions fluctuating at different frequencies.

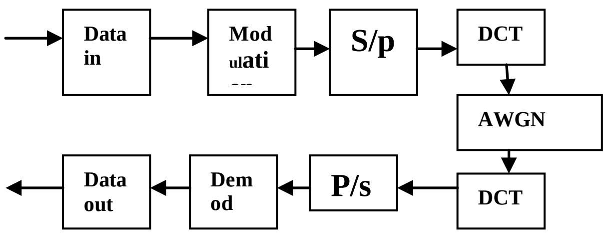

Fig. 2.1 DCT Based OFDM System

In DCT, based OFDM System Image is modulated by suitable modulation scheme. Here I am Using QPSK Modulation scheme. After converting the bit stream from serial to parallel, apply DCT transform method to each block of image. After that, transfer it through the AWGN (Additive White Gaussian Noise) Channel. In addition, at receiver side apply inverse DCT at each block of Image

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followed by parallel to serial converter and demodulation scheme. Finally, we receive compressed image.

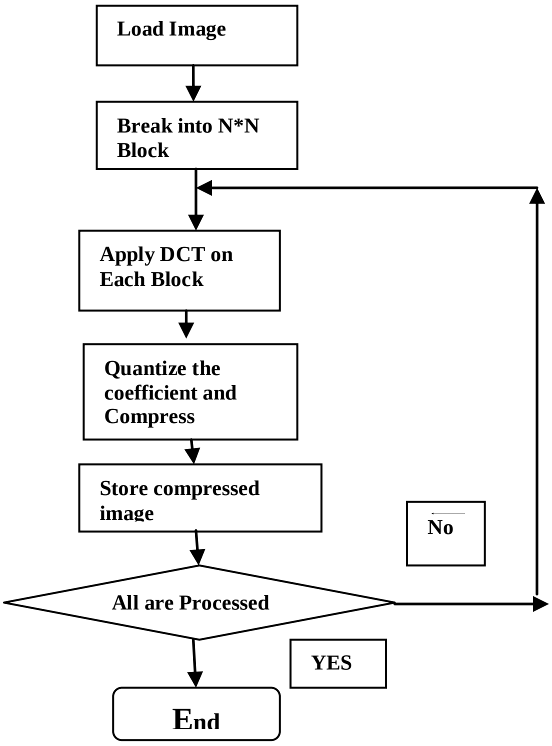

Fig. 2.2: DCT Coding Procedure

As shown in Fig 2.2. In DCT Coding, we first break the image in N*N blocks & apply DCT algorithm on each blocks, then rounded off the coefficients. That is called quantization process. After this, we stored the compressed image and check whether the all blocks are processed or not.

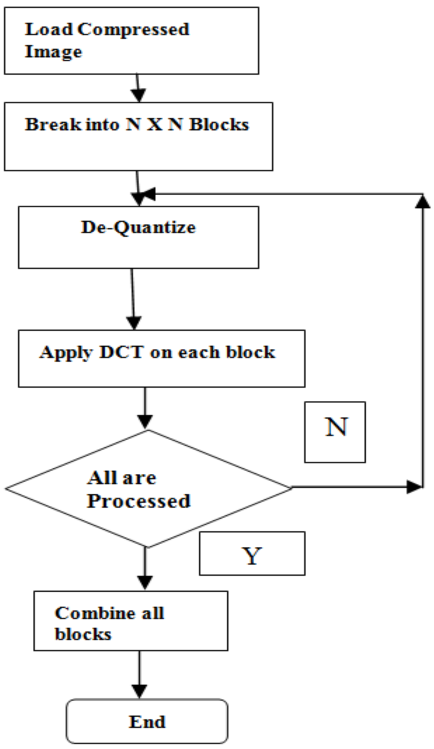

Fig. 2.3: DCT Decoding Procedure

If yes then our compression is done, else we apply DCT on remaining blocks again. Fig. 2.3 shows the DCT decoding procedure at receiver side, Firstly load compressed image then break it into N*N blocks. Thereafter each block will be de-quantized and then we apply inverse DCT transform on each block and at last combined them to get final image. For fast implementation algorithms, DCT can provide fewer computational steps than FFT based OFDM [2]. Because it deals only with the real numbers.

III. SIMULATION AND RESULTS

Here we are using MATLAB 2013 R for our simulation work. We are analysing DCT based OFDM system on different performance asset like PSNR(Peak Signal to Noise Ratio), MSE(Mean Squared Error) and BER (Bit Error Rate) at different SNR(Signal to Noise Ratio) by varying the compression level , modulation method and channel used.

Here we are varying different parameters mentioned below

- **Compression level**

1. 50% coefficient retained
2. 10% coefficient retained

- **Modulation Scheme**

1. QPSK
2. QPSK with convolution code

- **Channel Used**

1. AWGN (Rayleigh)
2. Fading Channel

- **50 % coefficient Retained + QPSK with Convolution coding +AWGN with fading**

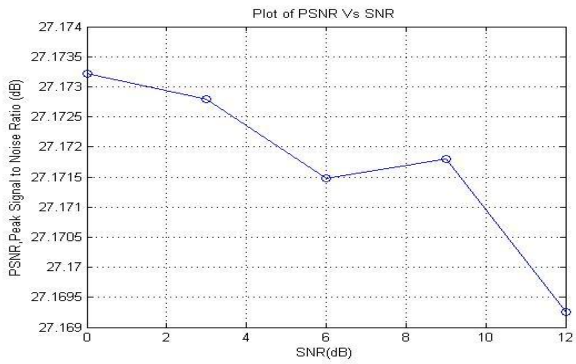

Fig.3.1 Plot of PSNR Vs SNR

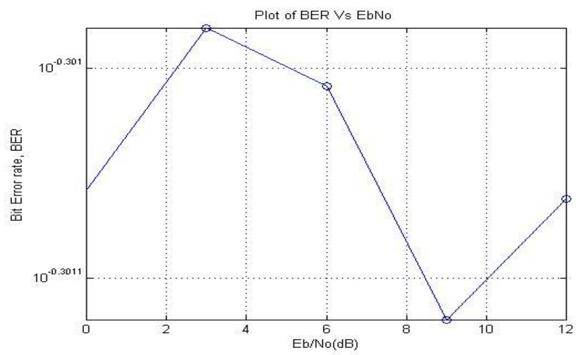

Fig.3.2 Plot of BER Vs Eb/No

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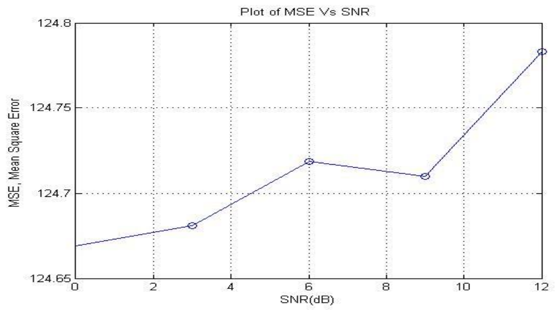

Fig. 3.3Plot of MSE Vs SNR

Table: 3.1 Values of BER, MSE, PSNR under first combination at different SNR

SNR (dB)	BER	MSE	PSNR(dB)
0	0.5000	124.6691	27.1732
3	0.5001	124.6810	27.1728
6	0.5000	124.7188	27.1715
9	0.4999	124.7099	27.1718
12	0.5000	124.7833	27.1693

MSE before transmission = 1.338 (AWGN)
PSNR before transmission = 46.86 db (AWGN)

- **50 % coefficient Retained + QPSK +AWGN with fading**

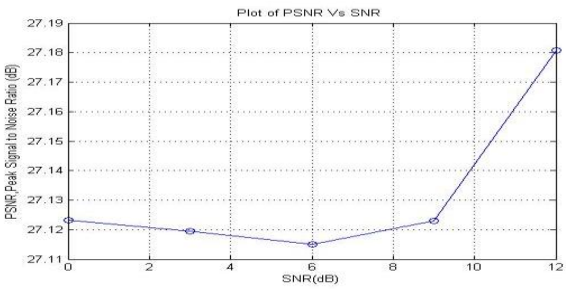

Fig.3.4 Plot of PSNR Vs SNR

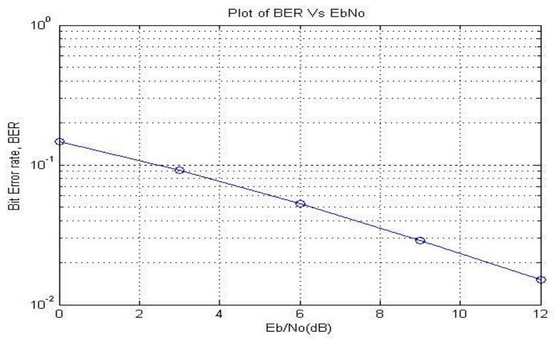

Fig.3.5 Plot of BER Vs Eb/No

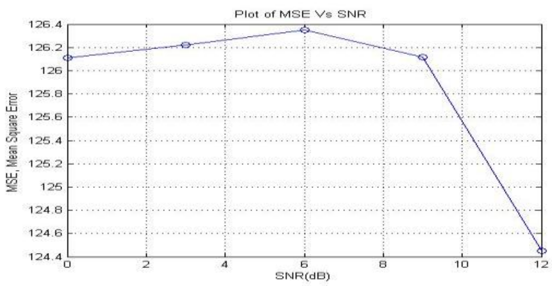

Fig.3.6 Plot of MSE Vs SNR

Table: 3.2 Values of BER, MSE, PSNR under second combination at different SNR

SNR (dB)	BER	MSE	PSNR(dB)
0	0.1467	126.1124	27.1232
3	0.0919	126.2227	27.1194
6	0.0529	126.35	27.1151
9	0.0289	126.1167	27.1231
12	0.0151	124.4501	27.1809

- **10 % coefficient Retained + QPSK +AWGN with fading**

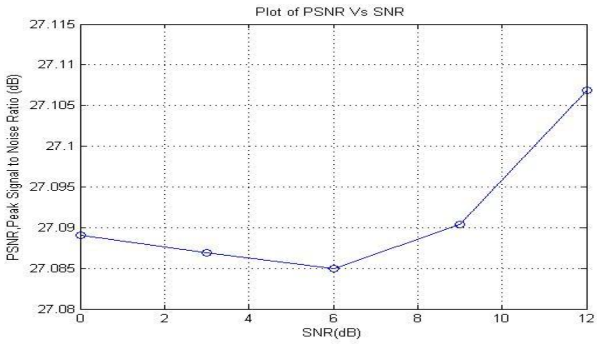

Fig.3.7 Plot of PSNR Vs SNR

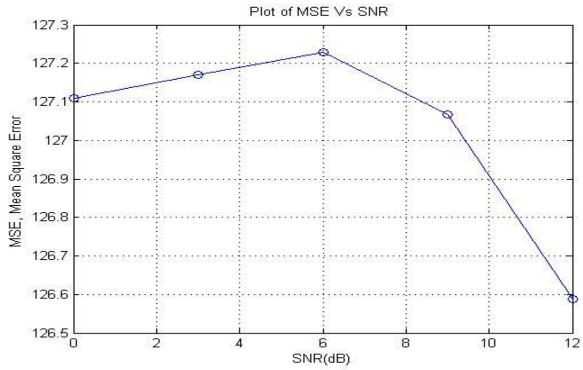

Fig. 3.8Plot of MSE Vs SNR

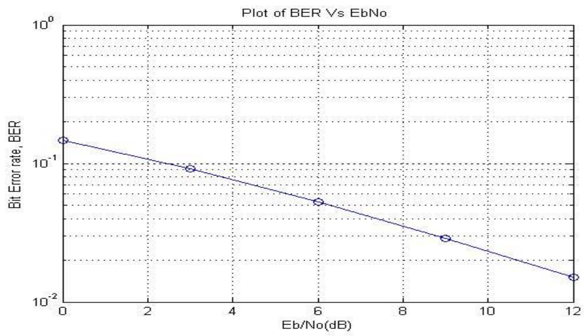

Fig. 3.9 Plot of BER Vs SNR

Table: 3.3 Values of BER, MSE, PSNR under third combination at different SNR

SNR (dB)	BER	MSE	PSNR(dB)
0	0.1464	127.1083	27.0891
3	0.0919	127.1706	27.0869
6	0.0529	127.2298	27.0849
9	0.0287	127.0683	27.0904
12	0.0150	126.5882	27.1069

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MSE before transmission = 10.40 (AWGN)
PSNR before transmission = 37.9584 db (AWGN)

- **10 % coefficient Retained + QPSK with Convolution coding +AWGN with fading**

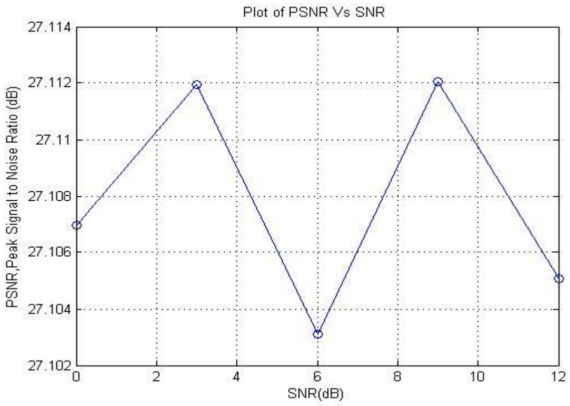

Fig. 3.10 Plot of PSNR Vs SNR

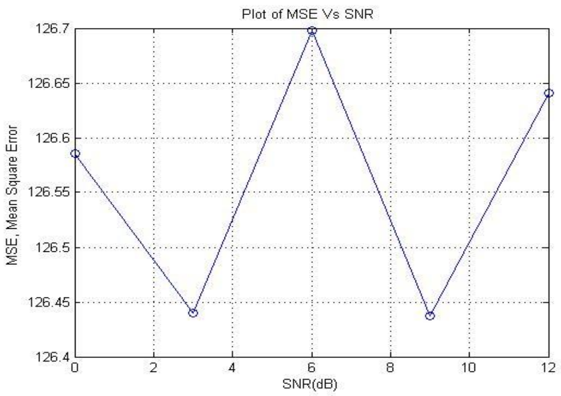

Fig. 3.11 Plot of MSE Vs SNR

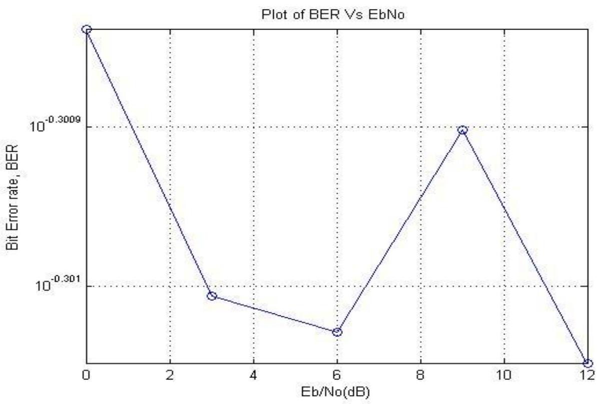

Fig.3.12 Plot of BER Vs SNR

Table: 3.4 Values of BER, MSE, PSNR under fourth combination at different SNR

SNR (dB)	BER	MSE	PSNR(dB)
0	0.5002	126.5857	27.1070
3	0.5000	126.4402	27.1120
6	0.5000	126.6981	27.1031
9	0.5001	126.4370	27.1121
12	0.5000	126.6408	27.1051

- **50 % coefficient Retained + QPSK +AWGN**

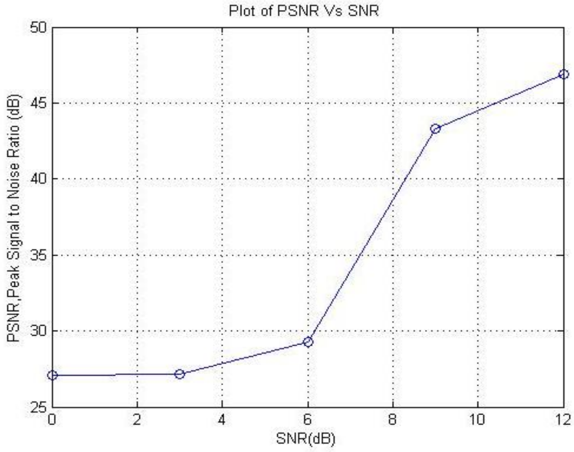

Fig.3.13 Plot of PSNR Vs SNR

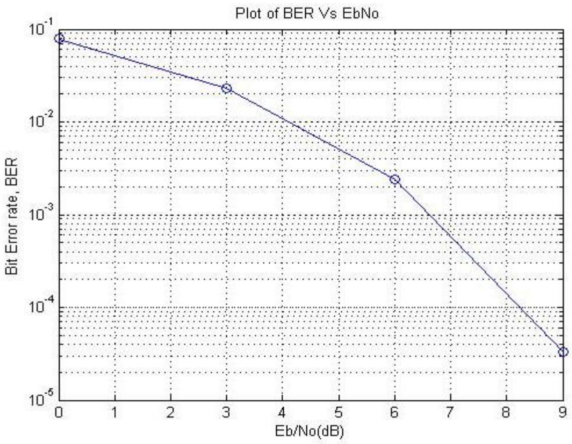

Fig.3.14 Plot of BER Vs SNR

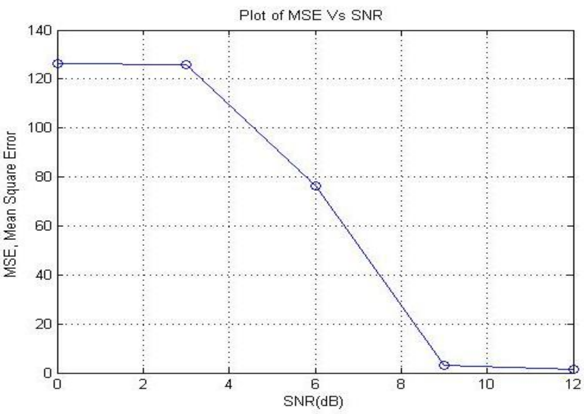

Fig.3.15 Plot of MSE Vs SNR

Table: 3.5 Values of BER, MSE, PSNR under fifth combination at different SNR

SNR (dB)	BER	MSE	PSNR(dB)
0	0.0787	126.2613	27.1181
3	0.0228	125.8301	27.1329
6	0.0024	76.1762	29.3126
9	$3.2951e^{-05}$	3.2284	43.3474
12	0	1.3385	46.8646

IV.CONCLUSION

In this research work initially we have formulated DCT-OFDM based image transmission and compression system .. We have formulated convolution encoding and compression ratio variations in DCT-OFDM system in both channels (AWGN & Fading). In AWGN Channel we gain better performance in terms of any performance asset. But when we use fading channel, it affects the assets. They decreased by their values. PSNR & MSE does not affect much more by varying the parameters. But ofcourse BER gives better result if we adopt QPSK as modulation scheme at higher SNR.

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